CHM129

Acid-Base Equilibrium: Strong Acid – Strong Base Titrations

1. Consider the titration of 25.0 mL of 0.100M HCl with a 0.100 M NaOH solution.

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$$

Determine the pH at the following points:

a. Initial pH (no NaOH added)
b. pH after the addition of 10.00 mL of NaOH
c. pH after the addition of 25.00 mL of NaOH
d. pH after the addition of 35.00 mL of NaOH

$$V_e = \frac{C_a V_a}{C_b} = \frac{(0.100M)(25.0mL)}{0.100M} = \underline{\underline{25.0mL}}$$

↑ equivalence volume

(a) strong acid solution

$[H_3O^+] = [HCl] = 0.100M$ $pH = -\log[H_3O^+] = -\log(0.100) = \underline{\underline{1.000}}$

(b) Excess HCl:
(10.00mL NaOH)

	HCl	+ NaOH	$\longrightarrow$ NaCl	+ H_2O
BA	2.50 mmol	—	—	
A	—	1.00 mmol	—	
AA	1.50 mmol	0	1.00 mmol	

neutral salt

$[H_3O^+] = [HCl] = \frac{1.50\,mmol}{35.0mL} = 0.0429\ M$ $pH = -\log(0.0429) = \underline{1.368}$

(c) Equivalence Point:
(25.00 mL NaOH)

	HCl	+ NaOH	$\longrightarrow$ NaCl	+ H_2O
BA	2.50 mmol	—	—	
A	—	2.50 mmol	—	
AA	0	0	2.50 mmol	

neutral salt

$[H_3O^+] = [OH^-] = 1.0 \times 10^{-7} M$ $pH = -\log(1.0 \times 10^{-7}) = \underline{\underline{7.00}}$

(d) Excess NaOH:
(35.00 mL NaOH)

	HCl	+ NaOH	$\longrightarrow$ NaCl	+ H_2O
BA	2.50 mmol	—	—	
A	—	3.50 mmol	—	
AA	0	1.00 mmol	2.50 mmol	

neutral salt

$[OH^-] = [NaOH]_{excess} = \frac{1.00\,mmol}{60.0\,mL} = 0.0167M$

$pOH = -\log[OH^-] = -\log(0.0167) = 1.778$ $pH = 14.00 - 1.778 = \underline{\underline{12.22}}$

CHM129

Acid-Base Equilibrium: Strong Acid – Strong Base Titrations (Practice)

1. Consider the titration of 30.0 mL of 0.100M KOH with a 0.200 M HNO_3 solution.

$$HNO_{3\,(aq)} + KOH_{(aq)} \rightarrow H_2O_{(l)} + KNO_{3\,(aq)}$$

Determine the pH at the following points:

a. Initial pH (no HNO_3 added)
b. pH after the addition of 5.00 mL of HNO_3
c. pH after the addition of 15.00 mL of HNO_3
d. pH after the addition of 25.00 mL of HNO_3

$$V_e = \frac{C_b V_b}{C_a} = \frac{(30.0\,mL)(0.100\,M)}{0.200\,M} = \underline{\underline{15.0\,mL}}$$

↑ equivalence volume

(a) Strong base solution

$[OH^-] = [KOH] = 0.100\,M$ $\quad pOH = -\log[OH^-] = -\log(0.100) = 1.000$

$pH = 14.00 - 1.000 = \underline{\underline{13.00}}$

(b) Excess KOH (5.00 mL HNO_3) : $HNO_3 + KOH \longrightarrow KNO_3 + H_2O$

	HNO_3	KOH	KNO_3	H_2O
BA	—	3.00 mmol	—	
A	1.00 mmol	—	—	
AA	0	2.00 mmol	1.00 mmol	

neutral salt

$[OH^-] = \frac{2.00\,mmol}{35.0\,mL} = 0.0571\,M$ $\quad pOH = -\log(0.0571) = 1.243$ $\quad pH = 14.00 - 1.243 = \underline{\underline{12.76}}$

(c) Equivalence Point : (15.00 mL HNO_3) $HNO_3 + KOH \longrightarrow KNO_3 + H_2O$

	HNO_3	KOH	KNO_3	H_2O
BA	—	3.00 mmol	—	
A	3.00 mmol	—	—	
AA	0	0	3.00 mmol	

neutral salt

$[OH^-] = [H_3O^+] = 1.0 \times 10^{-7}\,M$ $\quad pH = -\log(1.0 \times 10^{-7}) = \underline{\underline{7.00}}$

(d) Excess HNO_3 (25.00 mL HNO_3) : $HNO_3 + KOH \longrightarrow KNO_3 + H_2O$

	HNO_3	KOH	KNO_3	H_2O
BA	—	3.00 mmol	—	
A	5.00 mmol	—	—	
AA	2.00 mmol	0	3.00 mmol	

$[H^+] = [HNO_3]_{excess} = \frac{5.00\,mmol}{55.0\,mL} = 0.0909\,M$

$pH = -\log[H_3O^+] = -\log(0.0909) = \underline{\underline{1.041}}$

2. Consider the titration of 20.0 mL of 0.150M $HClO_4$ with a 0.120 M LiOH solution.

$$HClO_{4\,(aq)} + LiOH_{(aq)} \rightarrow H_2O_{(l)} + LiCl_{(aq)}$$

Determine the pH at the following points:

a. Initial pH (no LiOH added)
b. pH after the addition of 10.00 mL of LiOH
c. pH after the addition of 25.00 mL of LiOH
d. pH after the addition of 35.00 mL of LiOH

$V_e = \frac{C_a V_a}{C_b} = \frac{(0.150M)(20.0mL)}{0.120M} = \underline{\underline{25.0mL}}$

↑ equivalence volume

(a) Strong acid solution

$[H_3O^+] = [HClO_4] = 0.150M$ $pH = -\log[H_3O^+] = -\log(0.150) = \underline{\underline{0.824}}$

(b) Excess $HClO_4$ (10.00mL LiOH)

	$HClO_{4(aq)}$ +	$LiOH_{(aq)}$ →	$H_2O_{(l)}$ +	$LiCl_{(aq)}$
BA	3.00mmol	—		—
A	—	1.20mmol		—
AA	1.80mmol	0		1.20 mmol

neutral salt

$[H_3O^+] = [HClO_4] = \frac{1.80\,mmol}{30.0\,mL} = 0.0600M$ $pH = -\log(0.0600) = \underline{\underline{1.222}}$

(c) Equivalence Point (25.00mL LiOH)

	$HClO_{4(aq)}$ +	$LiOH_{(aq)}$ →	$H_2O_{(l)}$ +	$LiCl_{(aq)}$
BA	3.00mmol	—		—
A	—	3.00mmol		—
AA	0	0		3.00mmol

neutral salt

$[H_3O^+] = [OH^-] = 1.0\times10^{-7}M$ $pH = -\log(1.0\times10^{-7}) = \underline{\underline{7.00}}$

(d) Excess LiOH (35.00mL LiOH)

	$HClO_{4(aq)}$ +	$LiOH_{(aq)}$ →	$H_2O_{(l)}$ +	$LiCl_{(aq)}$
BA	3.00 mmol	—		—
A	—	4.20 mmol		—
AA	0	1.20 mmol		3.00 mmol

$[OH^-] = [LiOH]_{excess} = \frac{1.20\,mmol}{55.0\,mL} = 0.0218M$

$pOH = -\log[OH^-] = -\log(0.0218) = 1.661$

$pH = 14.00 - 1.661 = \underline{\underline{12.34}}$